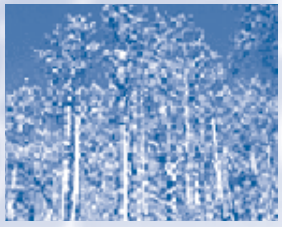
CLIMATE LEADERS GREENHOUSE GAS INVENTORY PROTOCOL

CORE MODULE GUIDANCE

Direct HFC and PFC Emissions from Use of Refrigeration and Air Conditioning Equipment



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This Guidance is based on the World Resources Institute and the World Business Council for Sustainable Development's GHG Protocol Initiative

CLIMATE LEADERS
U.S. Environmental Protection Agency

The Climate Leaders Greenhouse Gas Inventory Protocol is based on the Greenhouse Gas Protocol (GHG Protocol) developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The GHG Protocol consists of corporate accounting and reporting standards and separate calculation tools. The Climate Leaders Greenhouse Gas Inventory Protocol is an effort by EPA to enhance the GHG Protocol to fit more precisely what is needed for Climate Leaders. The Climate Leaders Greenhouse Gas Protocol consists of the following components:

- Design Principles Guidance
- Core Modules Guidance
- Optional Modules Guidance
- Reporting Requirements

All changes and additions to the GHG Protocol made by Climate Leaders are summarized in the Climate Leaders Greenhouse Gas Inventory Protocol Design Principles Guidance.

For more information regarding the Climate Leaders Program, e-mail climateleaders@epa.gov

Or visit us on the web at www.epa.gov/climateleaders

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Introduction

Historically, air conditioning and refrigeration equipment utilized various Ozone Depleting Substances (ODSs), primarily CFCs and HCFCs. However, in accordance with the Clean Air Act Amendments of 1990 (Title VI) and the Montreal Protocol, these ODSs are being phased out of manufacture and use in the United States. In the refrigeration sector, HFCs and, to a lesser extent, PFCs are used as substitutes for the regulated ODSs.

HFC emissions from the refrigeration and air conditioning sector result from the manufacturing process, from leakage and service over the operational life of the equipment, and from disposal at the end of the useful life of the equipment. These gases have 100-year global warming potentials (GWP), which are 140 to 11,700 times that of carbon dioxide (CO_2), so their potential impact on climate change can be significant (see examples in Table 1). By the same token, any reductions of these gases can have a large potential benefit.

This guidance document only addresses emissions from users of refrigeration/air conditioning equipment including household refrigeration, domestic air conditioning and heat pumps, mobile air conditioning, chillers, retail food refrigeration, cold storage warehouses, refrigerated transport, industrial process refrigeration, and commercial unitary air conditioning systems. Emissions associated with manufacturing refrigeration/air conditioning equipment are discussed in the *Core Module Guidance for Direct HFC and PFC Emissions From Manufacturing Refrigeration & Air Conditioning Equipment.*

Table 1: Global Warming Potentials

Common Name	Formula	Chemical Name	GWP*
HFC-23	CHF_3	trifluoromethane	11,700
HFC-32	CH_2F_2	difluoromethane	650
HFC-125	C_2HF_5	pentafluoroethane	2,800
HFC-134a	$C_2H_2F_4$	1,1,1,2-tetrafluoroethane	1,300
HFC-143a	$C_2H_3F_3$	1,1,1-trifluoroethane	3,800
HFC-152a	$C_2H_4F_2$	1,1-difluoroethane	140
HFC-236fa	$C_3H_2F_6$	1,1,1,3,3,3-hexafluoropropane	6,300
PFC-116	C_2F_6	hexafluoroethane ((perfluoroethane))	9,200
PFC-14	CF_4	tetrafluoromethane ((perfluromethane))	6,500

*Global Warming Potential from Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (1995).

1.1. Gases Included

Refrigerants include a number of different compounds including CFCs, HCFCs, HFCs, and PFCs, all of which have global warming potentials. As mentioned, CFCs and HCFCs are being phased out of production due to their ozone depleting properties. However, some entities still use CFCs and HCFCs directly or in refrigerant blends.

It is customary to exclude CFCs and HCFCs from greenhouse gas (GHG) inventories because they are regulated and are being phased out by the Clean Air Act and also because their global warming potentials are complicated by the fact that they deplete stratospheric ozone, which is also a greenhouse gas. Climate Leaders allows for reporting of CFCs and HCFCs as memo items on a Partner's inventory. They are reported as total release of gases but no global warming potentials are applied and they do not contribute to a Partner's total CO_2-Equivalent emissions inventory. Therefore, Partners that currently use CFCs or HCFCs and switch to HFCs or PFCs may show an increase in their overall GHG emissions inventory. Documenting the use of CFCs and HCFCs will account for this increase. In addition, Climate Leaders will consider shifts in CFC and HCFC use to HFCs and PFCs when evaluating a Partner's reduction goal if HFCs or PFCs from refrigerant switching are a significant emission source.

1.2. Manufacturing vs. Use Phase Emissions

This Core Module Guidance only applies to GHG emissions resulting from the use of refrigeration and air conditioning equipment. HFCs and PFCs may be released over the entire life of a refrigeration or air conditioning unit. All units can experience leaks throughout their operating life and catastrophic leaks may also occur. Also, when equipment is repaired or disposed of, HFCs and PFCs may be released if proper recovery processes are not used. Under the Climate Leaders reporting approach, Partners that use refrigeration and air conditioning equipment are only responsible for emissions that result at their own facilities. These emissions may take place during the installation, use, or disposal of equipment. Partners are not responsible for emissions that occur during the manufacturing of equipment that arrives pre-charged to their facility or from the mishandling of refrigerant sent offsite for third party recycling, reclaimation, or disposal. Guidance for estimating emissions from the manufacturing of refrigeration/air conditioning equipment is found in the *Core Module Guidance for Direct HFC and PFC Emissions From Manufacturing Refrigeration & Air Conditioning Equipment.*

Methods for Calculating Emissions

Most large companies will have emissions from refrigeration/air conditioning equipment in one form or another, however, the potential emissions sources and level of data available may differ greatly. For instance, a supermarket chain with large refrigeration systems may have on-site storage of refrigerants and track detailed data concerning refrigerant use while another company may simply use an air conditioning unit in its commercial office space. Consequently, three methods with varying levels of accuracy and data collection required are outlined below to estimate GHG emissions from the use of refrigeration/air conditioning equipment.

Section 2.1 describes a preliminary Screening Method to estimate emissions based on the type of refrigeration/air conditioning equipment used and emission factors. This method requires the least actual data collection and is used as a screening exercise to determine if refrigeration/air condition equipment emissions are significant when compared to a Partner's other emission sources (e.g., stationary combustion, mobile sources, etc.). If they are determined to be significant, it is recommended that one of the other methods be applied to better estimate emissions.

Section 2.2 describes a Material Balance Method of estimating HFC and PFC emissions from refrigeration/air conditioning equipment use. This method requires available data on the total inventory of refrigerants at the beginning and end of the reporting period, purchases during the reporting period, and changes in total nameplate capacity.

Section 2.3 describes a Simplified Material Balance Method that is appropriate for entities that do not maintain and track a stock of refrigerants and did not have any changes in their equipment capacity over the reporting period.

2.1. Screening Method

The following screening method is recommended to determine if refrigeration/air conditioning equipment may be a significant GHG emission source for a Partner compared to their other GHG emission sources[1]. Under this approach, a Partner multiplies the amount of refrigerant in the equipment by an emission factor for the specific type of equipment and emission event. The disadvantage to using this approach is that emission factors are highly uncertain. Therefore, this method is proposed as a screening test only. Consequently, if a Partner determines that emissions from refrigeration/air conditioning may be significant, it is recommended that one of the other methods then be used. It is also recommended that all Partners perform at least this Screening Method or one of the other methods to transparently determine whether or not refrigeration/air conditioning emissions are indeed immaterial. Estimating emissions with the Screening Method requires the following steps:

Step 1: Perform an inventory of equipment.
Determine the number and types of refrigeration/air conditioning equipment (by equipment category, see Section 4.1) including the types of refrigerant used and the refrigerant charge capacity of each piece of equipment.

1 See the *Climate Leaders Design Principles* for more on materiality and significance of emissions sources.

Step 2: Determine installation emissions. Identify any new equipment that was installed during the reporting period and was charged on-site. Emissions from equipment that was charged at the manufacturer are not the responsibility of the reporting entity for equipment use (see Section 1.2). For each new piece of equipment use Equation 1 to estimate emissions:

Equation 1: Estimating Emissions from Installation

Emissions from Installation = $C_N \times (k/100)$

where:

C_N = amount of refrigerant charged into the new piece of equipment

k = assembly losses in percent of amount charged

Step 3: Determine operating emissions. This step estimates losses from equipment leaks and service losses over the life of the equipment. For all pieces of equipment, use Equation 2 to estimate emissions:

Equation 2: Estimating Emissions from Operation

Emissions from Operation = $C \times (x/100) \times T$

where:

C = charge capacity of the piece of equipment

x = annual leak rate in percent of capacity

T = time in years used during the reporting period (e.g., 0.5 if used only during half the reporting period and then disposed)

Step 4: Determine disposal emissions. Identify any pieces of equipment that were disposed of during the reporting period. For each piece of disposed equipment, use Equation 3 to estimate emissions:

Equation 3: Estimating Emissions from Disposal

Emissions from Disposal = $C_D \times (y/100) \times (1 - z/100)$

where:

C_D = charge capacity of the piece of equipment being disposed of

y = percent of the capacity remaining at disposal

z = percent of refrigerant recovered

Step 5: Calculate total emissions. Add the emissions from each piece of equipment for each type of emission, installation, operation, and disposal to get total emissions. Calculate separate totals for each type of refrigerant used.

Section 4.1 provides default emission factors and describes the different categories of equipment for which there are default factors.

2.2. Material Balance Method

The Material Balance Method tracks emissions of HFCs and PFCs from refrigeration/air conditioning equipment use through a mass balance analysis. Releases of HFCs and PFCs can be calculated based on the inventory (storage not equipment) of refrigerants, purchases, sales, and changes in total capacity of equipment during the emissions reporting period. The

inventory should be tracked at the facility level by type of refrigerant. Equation 4 shows the basic principles involved in this approach.

Equation 4: Material Balance of Refrigerant

$I_B + P + C_B = I_E + S + C_E + \text{Emissions}$

where:

I_B = refrigerant in inventory (storage not equipment) at the beginning of reporting period

P = refrigerant purchased during the reporting period

C_B = total capacity of refrigerants in equipment at the beginning of the reporting period

I_E = refrigerant in inventory (storage not equipment) at the end of reporting period

S = refrigerant sold or otherwise disposed of during the reporting period

C_E = total capacity of refrigerants in equipment at the end of the reporting period

Equation 4 can be rewritten to more easily calculate emissions as shown in Equation 5.

Equation 5: Estimating Refrigerant Emissions with the Material Balance Method

$\text{Emissions} = I_B - I_E + P - S + C_B - C_E$

Equation 5 should be applied to each type of refrigerant used. Calculating emissions with the Material Balance Method requires the following steps for each type of refrigerant:

Step 1: Calculate the change in inventory. Subtract the inventory at the end of the reporting period from the inventory at the beginning of the reporting period to calculate the change in inventory. The inventory of refrigerants is defined as the total refrigerant stored on site in cylinders or other storage. This does not include refrigerants contained within equipment.

Step 2: Determine purchases and other acquisitions. Purchases and other acquisitions may include refrigerant purchased from producers/distributors, refrigerant provided by manufactures with or inside equipment, refrigerant added to equipment by contractors or other service personnel (but not if that refrigerant is from Partner's inventory), and refrigerant returned after off-site recycling or reclamation.

Step 3: Determine sales/disbursements. Sales/disbursements may include sales of refrigerant in containers or left in equipment that is sold, refrigerant returned to refrigerant suppliers, and refrigerant sent off-site for recycling, reclamation, or destruction.

Step 4: Calculate the change in capacity. The change in capacity is the net change to the total equipment volume for a given refrigerant during the reporting period. Note that "total capacity" refers to the full and proper charge of the equipment rather than the actual charge, which may reflect leakage. This term accounts for the fact that if new equipment is purchased, the refrigerant that is used to charge that new equipment should not be reflected in a Partner's inventory. Total capacity also accounts for refrigerant that has leaked from equipment over its lifetime, or the difference between

the full charge and the amount recovered from retired equipment. If the beginning and ending total capacity values are not known, this factor can be calculated based on known changes in equipment. The total full charge of new equipment (including equipment retrofitted to use the refrigerant in question) minus the full charge of equipment that is retired or sold (including full charge of refrigerant in question from equipment that is retrofit to use a different refrigerant) also provides the change in total capacity.

Step 5: Calculate emissions. Once the previous four steps have been completed, GHG emissions may be quantified using Equation 5.

As mentioned, this approach should be done for each type of refrigerant and refrigerant blend used. Section 4.2 describes in more detail the type of data that is used in determining emissions.

2.3. Simplified Material Balance Method

The Simplified Material Balance Method is a simplified version of the Material Balance Method described above because there are less flows of refrigerant to consider. This method requires information on the quantity of refrigerant used to fill any new equipment installed during the reporting period, the quantity of refrigerant used to service equipment and the quantity of refrigerant recovered from any equipment retired during the reporting period. It also requires information on the total full capacity of installed and retired equipment. This method can be summarized by Equation 6.

Equation 6: Estimating Refrigerant Emissions with the Simplified Material Balance Method

$$\text{Emissions} = P_N - C_N + P_S + C_D - R_D$$

where:

P_N = purchases of refrigerant used to charge new equipment (omitted if the equipment has been pre-charged by the manufacturer)

C_N = total full capacity of the new equipment (omitted if the equipment has been pre-charged by the manufacturer)

P_S = quantity of refrigerant used to service equipment

C_D = total full capacity of retiring equipment

R_D = refrigerant recovered from retiring equipment

The above equations should be applied to each type of refrigerant used. Calculating emissions with the Simplified Material Balance Method requires the following steps for each type of refrigerant:

Step 1: Calculate installation emissions. This step is only necessary if the reporting entity installed any new equipment during the reporting period that was not pre-charged by the equipment supplier. Emissions are calculated by taking the difference between the amount of refrigerant used to charge the equipment and the total capacity of the equipment. The difference is assumed to be released to the environment.

Step 2: Determine equipment servicing emissions. Equipment servicing emissions result from the refrigerant that is used to service operating equipment. It is assumed that the servicing refrigerant is replacing the same amount of refrigerant that was lost to the environment.

Step 3: Calculate disposal emissions. This step is only necessary if the Partner disposed of equipment during the reporting period. Emissions are calculated by taking the difference between the total capacity of the equipment disposed and the amount of refrigerant recovered. The difference is assumed to be released to the environment.

Step 4: Calculate emissions. Emissions are calculated by summing the results of the first three steps.

This approach should be done for each type of refrigerant and refrigerant blend used. Section 4.3 describes in more detail the type of data that is used in determining emissions.

Choice of Method

The Detailed Material Balance Method is recommended for Partners who maintain their own refrigeration/air conditioning equipment. This method requires data from refrigerant inventories, purchase and service records, and the full and proper charges of equipment. It includes emissions from equipment operation, servicing, and disposal.

The Simplified Material Balance Method is recommended for Partners who have contractors service their refrigeration/air conditioning equipment. This method tracks emissions from equipment operation, servicing, and disposal. The method requires data on the quantity of refrigerant used to fill new equipment during installation, the quantity of refrigerant used to service equipment, the quantity of refrigerant recovered from retiring equipment, and the full and proper charges of new and retiring equipment. If notified in advance of the need for this information, the contractor should be able to provide it.

It is recommended that the Screening Method be used only as a screening tool because the emissions factors used in the approach are highly uncertain. Emission factors vary between individual pieces of equipment and over time. Even if the amount of refrigerant added to a piece of equipment has been tracked carefully, permitting the previous leak rate of that equipment to be established, that leak rate can change after a leak is repaired or as the equipment ages.

Choice of Activity Data and Emission Factors

Required data for all emission estimation methods can come from inventory records, purchase records, repair reports, service records, and disposal records. Although refrigerant mixtures are used in many different applications, care should be taken to account for either the mixtures (such as R-507A) or the individual HFCs (such as HFC-143 and HFC-125). It is recommended to track usage in the same manner as records are maintained, generally on a refrigerant mixture basis, unless mixing of refrigerants is an activity performed by the Partner.

4.1. Screening Method

The Screening Method requires Partners to determine the following information:

- Type of Equipment
- Number of Units
- Refrigerant Used
- Total Refrigerant Charge for the Equipment (lb.)
- Assembly Emission Factor (%)
- Annual Leakage Rate (%)
- Percent of Capacity Remaining at Disposal (%)
- Recovery (%)

The Screening Method is based on the Tier 2 approach from the IPCC Good Practice Guidance. The IPCC guidance also includes a table of emission factors for the different phases of refrigeration/air condition equipment's life by equipment type. The IPCC table provides ranges of values for the different emission factors. However, since this method is intended as a screening approach under Climate Leaders it is recommended that the worst case scenario of the ranges be used. For emission factors this is the high range of factors and for recovery percents it is the low range of the values provided by IPCC. These values are provided in Table 2.

The ranges in capacity are provided for reference, Partners should use the actual capacity of their equipment. The IPCC good practice guidance does not provide estimates for the percent of capacity remaining at disposal (with the exception of mobile air conditioning units), therefore, a conservative factor of 100% should be used.

4.2. Material Balance Method

The recommended approach for refrigeration/air conditioning equipment users who maintain their own equipment is to estimate emissions based on the Material Balance Method. This method requires data that should be available from purchase and service records. The Material Balance Method requires Partners to collect the following data:

- Refrigerant inventory (in storage, not equipment) at beginning of year
- Refrigerant inventory (in storage, not equipment) at end of year

Table 2: Default Emission Factors for Refrigeration/ Air Conditioning Equipment

Type of Equipment	Capacity (kg)	Installation Emission Factor k (% of capacity)	Operating Emissions x (% of capacity/yr.)	Refrigerant Remaining at Disposal y (% of capacity)	Recovery Efficiency z (% of remaining)
Domestic Refrigeration	0.05–0.5	1	0.5	100	70
Stand-alone Commercial Applications	0.2–6	3	10	100	70
Medium & Large Commercial Refrigeration	50–2,000	3	30	100	80
Transport Refrigeration	3–8	1	50	100	70
Industrial Refrigeration including Food Processing and Cold Storage	10–10,000	3	25	100	80
Chillers	10–2,000	1	15	100	80
Residential and Commercial A/C including Heat Pumps	0.5–100	1	5	100	70
Mobile Air Conditioning	0.8–cars 1.2–light trucks	0.5	20	40	0

- Refrigerant purchased from producers or distributors in bulk
- Refrigerant provided by manufacturers with or inside of equipment
- Refrigerant added to equipment by contractors
- Refrigerant returned after off-site recycling or reclamation
- Sales of bulk refrigerant to other entities
- Refrigerant left in equipment that is sold to other entities
- Refrigerant returned to suppliers
- Refrigerant sent off-site for recycling or reclamation
- Refrigerant sent off-site for destruction
- Refrigerant capacity at beginning of year (in equipment, not storage)
- Refrigerant capacity at end of year (in equipment, not storage)

If beginning and ending capacity values are not known then the following information can be used:

- Total full capacity of new equipment using this refrigerant
- Total full capacity of equipment that is retrofitted to use this refrigerant
- Total full capacity of retiring or sold equipment that used this refrigerant
- Total full capacity of equipment that is retrofitted away from this refrigerant to a different refrigerant

Note: "Total full capacity" refers to the full and proper capacity of the equipment rather than to the actual charge, which may reflect leakage.

4.3. Simplified Material Balance Method

The Simplified Material Balance Method is the recommended approach for equipment users who have contractors service their equipment. If notified in advance of the need for this information, the contractor should be able to provide it. This method requires Partners to collect the following data:

- Refrigerant used to fill new equipment
- Refrigerant used to fill equipment retrofitted to use this refrigerant
- Total full capacity of new equipment using this refrigerant
- Total full capacity of equipment that is retrofitted to use this refrigerant
- Refrigerant used to service equipment
- Total full capacity of retiring equipment
- Total full capacity of equipment that is retrofitted away from this refrigerant to a different refrigerant
- Refrigerant recovered from retiring equipment
- Refrigerant recovered from equipment that is retrofitted away from this refrigerant to a different refrigerant

Note: "Total full capacity" refers to the full and proper capacity of the equipment rather than to the actual charge, which may reflect leakage.

Completeness

An assessment of emissions from the use of refrigeration or air conditioning equipment must be complete at a corporate and a facility level. From a corporate perspective, the inventory should include emissions from all types of refrigerants in all facilities owned, partially owned, or leased by the company. This is addressed in Chapters 2 and 3 of the *Climate Leaders Design Principles* that discuss setting the boundaries of the corporate inventory. Completeness of corporate-wide emissions can be checked by comparing the list of facilities included in the GHG emissions inventory with those included in other emissions inventories/environmental reporting, financial reporting, etc.

The GHG inventory should also be complete at the facility level and include all applicable sources of refrigerant emissions. If a third party is used for any component of refrigerant tracking, the third party should provide any necessary information. For the Screening Method, all pieces of equipment of all different types need to be accounted for. For the Mass Balance Methods, all activities and different types of refrigerants or mixtures should be tracked.

The completeness of activity data should be described, including listing any sources or refrigerant from which emissions were not estimated. As described in Chapter 1 of the *Climate Leaders Design Principles* there is no materiality threshold set for reporting emissions; it is up to the Partner to decide and justify which sources to exclude for materiality issues. Therefore, any sources that were excluded from the inventory should be documented and proof given that the excluded emissions are indeed immaterial.

The inventory should also accurately reflect the timeframe of the report. In the case of Climate Leaders the emissions inventory is reported annually and represents a year of emissions data. Therefore, the inventory should be complete in that all the refrigerants used during the reporting period are accounted for.

Uncertainty Assessment

There is uncertainty associated with all methods of calculating GHG emissions. As outlined in Chapter 9 of the *Climate Leaders Design Principles,* Climate Leaders does not recommend Partners quantify uncertainty as +/- % of emissions estimates or in terms of data quality indicators. The effort spent to perform such analysis would be better spent pursuing high quality inventory data.

It is recommended that Partners attempt to identify the areas of uncertainty in their emissions estimates and make an attempt to use the most accurate data possible. As mentioned, the emission factor approach to estimating emissions is highly uncertain. Factors vary between individual pieces of equipment and over time. Even if the amount of refrigerant added to a particular piece of equipment has been tracked carefully, permitting the previous leak rate of that equipment to be established, that leak rate can change after the leak is repaired or as the equipment ages.

The major uncertainty introduced in the material balance approaches occurs with recently installed equipment. Equipment can leak for two or more years before needing a recharge, so emissions over this period are not detected until after they occur. Despite this minor drawback, the material balance approaches provide a highly accurate estimate of emissions from this sector.

Reporting and Documentation

Partners are required to complete the Climate Leaders *Reporting Requirements* for use of refrigeration/AC equipment and report past year emissions annually. In order to ensure that estimates are transparent and verifiable, the documentation sources listed in Table 3 should be maintained. Good practice guidance for GHG inventory development dictates that these documentation sources should be collected to ensure the accuracy and transparency of the data.

Good practice guidance for GHG inventory development also dictates that documentation should take the form of hard copies whenever possible. However, electronic copies may be kept in certain cases. Electronic documentation should be maintained in a manner that cannot be altered. For example, if purchasing records were obtained from an Enterprise Resource Planning (ERP) System (such as SAP, Oracle, etc.), a download of the information from the main system should be obtained and not just a link to the system. Data may be archived from the ERP at any time, and the link would then not work when an audit was being performed.

Table 3: Documentation Sources

Data	Documentation Source
Inventory at Beginning and End of Year	Stock Inventory documentation
Purchases	Purchase receipts; delivery receipts; contract purchase or firm purchase records
Nameplate Capacity of Equipment	Delivery receipts of equipment; records of physical inspection of nameplates; shipping or disposal records of equipment
Amounts Charged to Equipment	Repair records; repair invoices; daily reports
Amounts Recovered from Equipment	Repair records; repair invoices; daily reports; disposal records

Inventory Quality Assurance and Quality Control (QA/QC)

Chapter 9 of the *Climate Leader Design Principles* provides general guidelines for implementing a QA/QC process for all emission estimates. For the use of refrigeration and AC equipment the following items must be addressed:

- Care should be taken that releases are not double-counted (e.g., from reporting both refrigerant blend and individual blend component use).
- Verify that your inventory is complete. Because the GWPs of HFCs and PFCs are so large, failure to account for even relatively small releases of HFCs and PFCs can make a big difference when the releases are converted to a CO_2-Equivalent basis. Also, tracking HFC and PFC separately is important, because of the differing GWPs.

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